STEVE STURGESS - on everything trucks

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The No Cam, No Crank, No Carbon Engine

The first time I visited Sturman Industries, I found a handsome office building perched high on a mountain in Woodland Park, Colorado. Inside, people gaze out of the three-story windows at the breathtaking views of the mountains. They are being creative. They are the engineers of Sturman Industries.

And the creations of the 40 or so managers, engineers and technicians all lead in one direction: environmental care through advances in the management of fuel and air in an internal combustion engine. This is done by controlling emissions, performance and economy independently of conventional mechanically-connected camshaft and crankshaft.

Sturman Industries is a research and development hothouse. Its designs are licensed. And many are based on the digital valve technology, originally developed by Eddie Sturman for the Apollo space program of the mid-60s. Sturman Industries was created by Eddie and Carol Sturman to develop and commercialize applications for his innovative latching digital valve.

A great example is the International hydraulically actuated unit fuel injector: Sturman was a technology partner and enabler for the HEUI injector. Pure Power Technologies, owned by Navistar, is currently churning out thousands of injectors a day.

A fundamental differentiator of the hydraulic unit injector, like the common rail injector, is that it can be removed from the constraints of mechanically driven camshaft actuation where the unit injector, unit pump and even PLN injectors have to rely on the profile and timing of a camshaft for their operation. The latest electronically controlled injectors – common-rail or HEUI -- are now completely independent of crankshaft position. Not only can they feature widely variable injection timing, but multiple injection events are enabled within the same compression stroke.

For Eddie Sturman, though, independent fuel control is only half the solution – and maybe less than half. What he sees is similar control of the air handling in the engine. On a later visit this control has grown to include piston position as well, but we'll return to that in a moment.

The electronic/hydraulic camshaft Sturman industries developed over a decade ago is like the injection event: the hydraulic valve activation completely decouples valve position and movement from the crankshaft position by eliminating the conventional camshaft altogether.

And it's not hard to do. As Sturman points out, if you can inject fuel into an engine at 30,000 psi using the engine's own hydraulics, cracking open a few poppet valves is a very simple task.

Once the valves are freed from camshaft control, engine designers can set about optimizing valve timing, lift and other valve events with complete freedom, controlling combustion in the cylinders with a whole new set of tools unavailable within the constraints even of a variable timing arrangement on a conventional camshaft.

Sturman has already demonstrated the technology in International trucks, one of which has driven up Pikes Peak (which you can see from Sturman Industries' windows) and in a second demonstration, in a much more extensive coast-to-coast run more than a decade ago when the camless engine showed it could run quietly and efficiently for more than 10,000 miles in an International 8100 medium-duty chassis. That truck, incidentally, sits in a barn on the Sturman property in Woodland Park.

It is exciting stuff, but because it is revolutionary and, even now, is still some way in the future. Sturman says, however, that large scale production program plans are forming in more than one mobility sector. The technology to open and close valves hydraulically is not particularly demanding. The challenge is deciding what and how much the industry needs of the available technology that has already been designed and developed in a workable engine.

Even if it takes years to commercialize in a production engine, an engine designer has an incredibly powerful design tool in camshaft-less valve actuation. In design iterations, the hydraulically actuated valve timing with variable lift allows the designer in real time, on a dynamometer, to adjust "cam" profiles, lift and overlap, timing and valve ramp speed without having to go back and grind another camshaft every time a change is desired.

Those same capabilities in a closed-loop control situation could mean the valve timing and lift can be varied throughout the operating range of a production engine, allowing for control that can vary each cylinder's performance to supply only the horsepower required from the foot pedal's position.

And, of course, features like individual cylinder deactivation and engine retarder functions come along with the package absolutely free of charge.

While this ability to control the fuel and the air in an engine is remarkable, it is only the introduction to what those engineers looking out over the Colorado Mountains see in the future. Commercialization of these technologies may be several years away, but ultimately, Sturman sees the development of an environmental engine. It is a diesel, but it incorporates hydraulically actuated valves that enable pumping cylinders to provide a supercharger capability when it is desired. It has the completely decoupled fuel control, with a number of Sturman advantages, not least of which is safety through a completely contained high pressure system within the injector (unlike a common rail) and exceptional combustion control that minimizes exhaust aftertreatment.

And here's the kicker: eliminate all that complicated mechanical drive and linkage that is part of the camshaft and valvetrain and you're saving cost and weight as well.

The Problem

De-coupling the valve actuation from crankshaft rotation and timing is not an exclusive Sturman research project. Others realize electronic valve control opens up all kinds of design opportunities of valve timing, lift, duration, event – you name it. Valeo, the French component supplier has been pursuing camless engine design claiming it could offer 20% fuel savings in cars.

Given such savings, why has the concept not taken off like a bottle rocket?

Well, to quote Eddie Sturman, the problem is that engine designers have sought to replicate conventional valve movement, using the hydraulic actuation instead of the camshaft as in the design scenario postulated earlier. According to Sturman, that's like taking a concert grand piano and playing Chopsticks. What's needed, says Sturman, are whole new symphonies.

And in the absence of the new music, Sturman has come up with his own – a new cycle that is only possible with decoupled valve actuation. And one that seeks to move diesel thermal efficiency from around 42% up to as much as 60% -- with near-zero emissions and no aftertreatment.

The Sturman cycle retains exhaust in cylinder at the bottom of the expansion stroke and fuel is injected into this hot exhaust as the piston starts the compression stroke. Key to the engine's low emissions is that the fuel evaporates in the hot gas, truly atomizing unlike high pressure fuel even at 2200 bar (32,000 psi). It does not burn immediately, as the hot gas is inert. However, combustion is initiated as the piston rises on the compression stroke by opening the inlet valves to a compressed air charge. As the piston heads down the expansion stroke, more air is mixed with the charge in the cylinder to maintain combustion and in-cylinder pressure. This gets more work out of the fuel charge, with far lower flame temperatures and injection pressures. And because the fuel is vaporized there's no particulate matter formation as is obtained from burning droplets of fuel.

Electronic/hydraulic manipulation of the valves means the engine is a two stroke. And by varying valve timing and fuel delivery, cylinders can be power-producing or air compressing or just windmilling.

So now you have an engine with a hydraulic rail, air rail and high voltage (Internationals have 300V plus at the injectors). So you also have the right elements to pair the Sturman-cycle engine with compressed-air, hydraulic or electric hybrids.

More remarkably yet, because the engine cycle is controlled electronically (not by cam profile and timing chain) the power unit can switch back and forth between Sturman, homogeneous charge compression ignition (HCCI), or conventional diesel cycles -- or any other exotic cycle that can be created for the good old piston engine.

Is there no end to the camless engine versatility? Apparently not. It'll run on anything that can be squeezed through the injector and that includes a bottle of pure Canola oil that Eddie Sturman took into the lab to prove the point.

And Now, the Impossible
Not content with the control afforded by decoupled fuel and air control, Sturman is looking at independent piston control through the elimination of the crankshaft.

To understand how this can be possible, you have to remember Sturman is a hydraulics engineer as well as a deep thinker. His injectors are in the straight six-cylinder engines that have earned all those emissions credits for Navistar over the last few years.

Sturman's latest concept is, of course, hydraulics-based. It uses a free floating piston that has a hydraulic connecting rod that positions the piston in the bores – in the case of the prototype currently being assembled, these is a custom-made piston in a single International cylinder liner.

Other hydraulic cylinders under the piston, together with the positioning cylinder convey the force generated in combustion to hydraulic pressure. This, instead of rotary motion of a crankshaft, becomes the energy output from the power unit.

Conventional poppet valves, also controlled hydraulically as in the earlier camless engine, manage the flow of air through the combustion chamber. So at a stroke, Sturman has control of air, fuel and piston position completely independently. He can change compression ratio, displacement, injection timing, air flow through valve opening and closing completely independently of piston position. This engine can even idle cylinders with pistons not moving, saving the pumping losses that are associated with more conventional cylinder cut-out configurations. Or, alternatively, make some cylinders air pumps to supercharge the engine. The possibilities are endless.

But the most important may be the fact that the engine can run on almost any fuel.

"How about a completely carbon-free fuel?" asked company president Carol Sturman over lunch one day recently.

I was a little taken aback. I had not thought of the chemistry before, but what burns in an internal combustion engine is the hydrogen that is associated with the carbon in a conventional hydrocarbon fossil fuel. You can squirt hydrogen into an engine and it'll run quite well with only water as the combustion product – as in a fuel cell, for instance – but hydrogen is a difficult fuel to manage. But combine that hydrogen with nitrogen in ammonia and the NH3 molecule becomes a prefect carrier for the hydrogen.

"An ammonia fuel?"

And why not? In WWII, buses in Belgium were run on ammonia. Various demonstration projects have shown it is a viable fuel, though engines have to be converted to run on it as it is fairly difficult to light off. But Sturman's concept engine with its infinitely controllable combustion is a perfect candidate.

Even discounting the freedom from oxides of carbon and their greenhouse-gas effects, just think about an ammonia-fuel economy. Ammonia is already the second largest manufactured chemical in use today. Farming pours billions of tons of ammonia onto crops every year. It is manufactured today from natural gas, but it can equally well be produced electrolytically from water and air.

We wouldn't have to drill for it in sensitive environments or suffer the consequences of spills. More importantly, we wouldn't have to obtain fuel supplies from politically unstable areas of the world where currently we spend billions of dollars a day supporting America's declared enemies.

It was a conversation that sets up a new way of thinking and new solutions to other possible issues far removed from internal combustion engines for on- and off-highway vehicles.

There's widespread concern about the dangers of electro-magnetic fields and high-voltage transmission lines. Not that I am necessarily a subscriber to that notion. But Both Eddie and Carol Sturman are championing distributed electrical power generation at a time when the power gen industry is coming to realize what a formidable task is renewing the electrical power generation infrastructure.

Distributed generation is more efficient: you have none of the huge losses involved in distribution of electricity, even at super high voltages. I believe that as much as 90% of the power generated is lost on the way to distant distribution points.

And using distributed generating sites powered by individual Diesel or Sturman engines you can bring on and take off as much capacity as the load requires, running each machine at maximum efficiency instead of one big plant at part load.

If you can use the current ammonia distribution infrastructure which is well developed to generate electricity locally using ammonia burning internal combustion engines, you have addressed the whole electrical distribution and power-grid issue, the dependence of foreign oil and the greenhouse gas issue all at a stroke.

Then like those engineers, we can spend our time more creatively looking out of the windows at the Colorado countryside. Just seeing more clearly and safely.

Posted by Steve Sturgess at 11:55 AM